DIVERSE STATURE ESTIMATION FORMULAE APPLIED TO A BOSNIAN POPULATION

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Abstract

Since 1996, the Trotter formulae, developed on American Whites, have been used almost without exception to determine the stature of the population in Bosnia and Herzegovina. In 2002, Ross and Konigsberg presented new formulae for stature estimation for Balkans, using bones from unidentified Bosnian and Croatian males, victims of the recent war. The same year, 2002, in his master thesis, Sarajlić also presented formulae for stature estimation of Bosnian population. The research was undertaken on male cadavers. The cadaver length was measured directly and the length of the long bones was obtained from radiographs.
However, none of these formulae were tested on the bones from exhumed persons. This study compares all three methods on a large independent sample in order to determine which formulae provide the most accurate stature estimation for the male population in Bosnia and Herzegovina. The sample for this research consists of long bones (humerus, femur, tibia and fibula) and was obtained from 369 exhumed and identified Bosnian males. Bones from the left side of the body were tested. Not all of them were present in each case: 211 left humeri, 270 left femura, 273 left tibiae and 175 left fibulae. Data about height was recollected by family members. Apart of whole sample, all three methods were applied separately on individuals taller then 180 cm.
Of all three tested methods formulae proposed by Sarajlić et al. folowed by Ross and Konigsberg formulae, produced significantly better results in stature estimation of tall persons.

KEY WORDS: Forensic sciences, forensic anthropology, Stature estimation, Bosnian population

Introduction

More then 10 000 persons from the recent war in Bosnia and Herzegovina are still missing. Several thousand exhumed remains are in process of identification. The key feature in every identification, supported by DNA or not, is determination of biological profile, based on estimation of sex, age and stature. Completed results are compared with antemortem data about missing person, obtained from family members. Since 1996, the Trotter and Gleser formulae (1, 2, 3), developed on American Whites,

have been used almost without exception to determine the stature of the population in Bosnia and Herzegovina. In 2002, Ross and Konigsberg (4) presented new formulae for stature estimation for Balkans, using bones from unidentified Bosnian and Croatian males, victims of the recent war. Because the actual statures of those persons were not known, the authors used the mean and standard deviation of stature for 19-year-old males from the literature. The same year, 2002, Sarajlić also presented formulae for stature estimation of Bosnian population (5). The research was undertaken on male cadavers. The cadaver length was measured directly and the length of the long bones was obtained from radiographs. There were no statistically significant differences between the length of the bones from the left and right sides of the body. Therefore, formulae developed from the average length of bone pairs were recommended for use (6). However, none of these formulae were tested on the bones from exhumed and identified persons. Therefore the main purpose of this study is to compare all three methods on a large independent sample in order to determine which formulae provide the most accurate stature estimation for the male population in Bosnia and Herzegovina.

Material and Methods

The maximum length (7) of long bones (humerus, femur, tibia and fibula) from both sides, were measured from 369 males exhumed and identified in north-west part of Bosnia. In each case, the identity of deceased persons was provided by DNA and confirmed by the comparison of antemortem and postmortem data. All individuals in the study were aged from 19 to 58 years. All bones were not present in each case so the sample consists of 211 left humeri, 270 left femora, 273 left tibiae, 175 left fibulae, 207 right humeri, 175 right femora, 240 right tibiae and 162 right fibulae. Considering the larger number, only the bones of left side were used for this research. Antemortem data about the height of identified persons was recollected by family members. In only 2% of the cases families reported the exact stature of the missing or there were either military or medical records of stature of those persons. In other cases, whenever possible, measurements of a surviving male cousin, who were mature before the war, were taken and the height of the missing person was estimated according to their height. Three groups of stature estimation formulae were used: Trotter and Gleser (1) for humerus, femur, tibia, fibula and the sum of lengths of femur and tibia; Ross and Konigsberg (4) equations for humerus, femur and tibia and formulae developed by Sarajlić et al. (6) according to length for femur, tibia, fibula and the sum of lengths of femur and tibia. Differences between absolute mean errors from the antemortem stature of all three models were analyzed. Two-way ANOVA with Tukey-Kramer test was applied. In the cases where it was possible to compare only two formulae (humerus, fibula and the sum of lengths of femur and tibia), pared t-test was used. The level of significance was 0,05. Apart from the whole sample, all three models were tested separately for the individuals taller then 180 cm.

	Stature	Humerus	Femur	Tibia	Fibula
Mean	176,63	33,79	47,46	38,68	38,21
Standard Error	0,35	0,12	0,14	0,13	0,16
Standard Deviation	6,68	1,17	2,32	2,23	2,06
Minimum	160	29,4	42,4	31,1	32
Maximum	203	39,4	54,8	45,4	44,6
N	369	211	270	273	175

Mean: Absolute mean error; N: Sample number;
All values are presented in cm

TABLE 1. Descriptive statistics for reported stature and measured length of the long bones

Results

Descriptive statistics for reported living stature and measured length of the long bones are presented in Table 1. Table 2 presents descriptive statistics for the mean difference from the real stature for each bone and for the sum of lengths of femur and tibia applying all three methods. Sarajlić et al. formulae (6) demonstrate the lowest divergence, followed by Ross and Konigs-

	Humerus		Femur			Tibia			Fibula		Femur + Tibia	
	Ross	Trotter	Ross	Trotter	Sarajlić	Ross	Trotter	Sarajlić	Trotter	Sarajlić	Trotter	Sarajlić
Mean	3,63	4,04	3,14	3,22	3,14	3,27	4,19	3,12	3,58	3,46	2,94	2,90
SE	0,20	0,21	0,15	0,15	0,15	0,15	0,18	0,14	0,21	0,20	0,14	0,13
SD	2,87	3,11	2,53	2,54	2,40	2,46	2,92	2,36	2,76	2,71	2,18	2,04
Min.	0,00	0,05	0,01	0,01	0,02	0,02	0,08	0,01	0,00	0,03	0,00	0,05
Max.	13,24	14,98	16,54	13,58	14,26	12,97	14,79	11,74	13,78	10,98	10,43	10,27
N	211	211	270	270	270	273	273	273	175	175	231	231

Mean: Absolute mean error; SE: Standard error; SD: Standard deviation; Min.: Minimum; Max.: Maximum;
N: Sample number; All values are presented in cm

TABLE 2. Descriptive statistics for mean for all three methods

	Femur			Tibia		
	Ross	Trotter	Sarajlić	Ross	Trotter	Sarajlić
Mean	4,97	5,14	4,36	4,99	6,56	3,26
SE	0,38	0,39	0,35	0,40	0,42	0,29
SD	2,99	3,12	2,78	3,02	3,21	2,18
Min.	0,33	0,17	0,03	0,38	0,21	0,06
Max.	11,71	11,92	10,94	12,97	14,79	8,19
N	63	63	63	58	58	58

Mean: Mean: Absolute mean error; SE: Standard error;
SD: Standard deviation; Min.: Minimum;
Max.: Maximum; N: Sample number;
All values are presented in cm

TABLE 3. Descriptive statistical analysis of mean for the persons taller then 180 cm

berg (4) and then Trotter and Gleser (1) equations. Only when Sarajlić et al. (6) and Ross and Konigsberg (4) formulae were applied for femur there were no differences in absolute mean error and standard error of the estimates, however standard deviation is lower using Sarajlić et al. (6). Results of statistical analysis for humerus showed signicantly better stature estimation with Ross and Konigsberg formula (4) in comparison to Trotter and Gleser formula (1). On the other hand, there were no significant differences in stature calculation from length of fibula and the sum of lengths of femur and tibia between different authors. Identical results were obtained for the femur. No significant differences were found whe using Ross and Konigsberg (4) and Sarajlić et al. (6) formulae for tibia but both equations significantly better calculate stature of Bosnian population then Trotter and Gleser (1) formula. Practical use and previously published study (6) showed that Trotter and Gleser formulae (1) especially underestimate the stature of tall individuals. Therefore, separate analysis was performed for the individuals taller then 180 cm. Results of descriptive statistical analysis were presented in Table 3. Deviations from the real stature were higher in comparison to the total sample but they were lowest when Sarajlić et al. (6) formulae were used. Results of two-way ANOVA analysis with Tukey-Kramer test confirmed significant differences between all models except among Ross and Konigsberg (4) and Trotter and Gleser (1) formula for femur.

Discussion

Determination of biological profile including estimation of stature is particularly important during the process of identification of the remains exhumed from the mass graves, especially secondary mass graves with highly commingled skeletal remains (8, 9). High costs are limitation factor for taking huge number of samples for DNA analysis. Considering that, comparison of antemortem and postmortem data, based on estimation of biological profile, is crucial for determination that all bones from the one case belong to the same individual. An additional problem in Bosnia and Herzegovina is lack of records for either measured or reported height of the missing. The majority of military records containing such data were destroyed during the war. Therefore, in more then 95% of cases data about height of missing persons were obtained from family members. Variations of the height depending on the part of the day are known (10). Inaccuracies of height information obtained from driver's licenses were reported (11, 12). Ousley (13) stated that forensic stature should be preferred to biological stature. According to him, biological stature is anyhow not known in forensic cases and therefore forensic stature, like those reported on driver's licenses, is more relevant. Given the absence of antemortem data for the height of the missing, estimated forensic stature (by close relatives) has to be considered as equivalent to biological stature in this situation. Ross and Konigsberg showed in their research that formulae based on Trotter and Gleser (1) systematically underestimate stature in the Balkans. Sarajlić et al. (6) stated that the Trotter and Gleser (1) formulae underestimate the stature of tall people in Bosnia. In his study (6), the comparison with Trotter and Gleser's method (1) was made with the same sample from which the new formulae were derived. However, none of these formulae were tested on the bones from exhumed and identified persons. Present research, considering the whole sample, confirmed that of all three tested models Sarajlić et al. formulae (6) give the most accurate and the most precise stature estimation of identified persons in Bosnia and Herzegovina. The lower value of absolute mean error and standard error were considered as the measures of accuracy and precision (14). Sarajlić et al. (6) and Ross and Konigsberg (4) formulae for femur were only exception, with identical mean absolute difference and standard error of estimate. None of the used models produced significantly better estimates of stature of Bosnian population. The critical significant difference was found only for Ross and Konigsberg (4) formula for humerus and Sarajlić et al. (6) and Ross and Konigsberg (4) formulae for tibia. Pelin and Duyar (15) showed that stature-group-specific formulae categorized as short (1652 mm and below), medium (1653 to 1840 mm), and tall (1841 and above), were more accurate than all other equations,

developed on whole sample. In their previous research, Sarajlić et al. (6) established underestimation of stature of individuals taller then 185 cm by Trotter and Gleser (1). Therefore, in this study, all three methods for femur and tibia were tested on separate sample of individuals taller then 180 cm. Sarajlić et al. (6) equations produced significantly better stature estimation. However, in the last example femur and tibia were used as independent variables. It is known that significant variations in femur – tibia/fibula ratio in single individual could exist (16). Therefore it is recommendable to use formulae derived from the sum of the lengths of femur and tibia or sum of the length of femur and fibula whenever it is possible.

Conclusion

Of all three tested models Sarajlić et al. (6) produced the best results in stature estimation for tall persons, folowed by Ross and Konigsberg formulae (4). Sarajlić et al. (6) equations were the most accurate and precise for the whole sample. This research emphasized need for developing stature estimation formulae on large sample of exhumed and identified persons, for the complete sample and stature-group-specific formulae. That might produce more accurate stature estimation, improving the process of identification of missing persons.

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